FINAL TECHNICAL REPORT

for grant titled

BIOGEOCHEMICAL PROCESSES IN SAGEBRUSH STEPPE: INTERACTIONS OF TERRAIN, VEGETATION AND CHEMICAL CYCLES

(NASA-Ames Agreement No. NAG 2-355)

prepared by

William A. Reiners

Department of Botany
The University of Wyoming
Laramie, Wyoming 82070
(307)766-2235

For the period 1 June 1985 to 29 February 1988

INTRODUCTION

This is the terminal report on a subcontract between the University of Wyoming and NASA/Ames (NAG 2-355) for work contributing to an award made to NASA/Ames under the NASA Announcement of Opportunity titled "Thematic Mapper Research in the Earth Sciences" (A.O. No. OSSA-3-84). This report consists of lists of publications, manuscripts in various stages of progress, presentations made at scientific meetings, and undergraduate honors thesis and one Ph.D. dissertation. Because this was a collaborative effort with NASA/Ames personnel (P.A. Matson and L.L. Strong), this report contains references to products produced or planned by all persons involved in this effort, not just by University of Wyoming personnel. Copies of two reprints and three preprints (one a galley proof) are attached.

Although funding for this project ended in February, 1988, synthesis is continuing through manuscript preparation until the publication goals listed below are met.

Ph.D. DISSERTATION

Burke, I.C. Distribution and turnover of nitrogen in a sagebrush landscape. Ph.D. Dissertation. University of Wyoming, Laramie, WY. 140 p.

UNDERGRADUATE STUDENT HONORS THESIS

Vinton, M.A. 1987. Distribution and nitrogen-fixing activity of Lupinus argenteus on sagebrush-steppe in Wyoming. Undergraduate honors thesis, Department of Botany, University of Wyoming. 37 p.

ABSTRACT: Distribution of Lupinus argenteus, a conspicuous legume

on sagebrush-steppes of Wyoming, is largely relegated to stands of Artemisia tridentata ssp. vaseyana (mountain big sage) which are typically located on more mesic positions of the landscape. The nitrogen-fixing activity of the nodules as measured in the field via the actylene-reduction assay is comparatively high. Consequently, nitrogen fixed per unit area within mountain big sage-dominated stands is significant. The amount of nitrogen fixed per unit area averaged over the entire landscapes, however, is much lower. Nitrogen fixation by Lupinus argenteus is primarily significant on a local scale within the landscape.

PUBLICATIONS AND MANUSCRIPTS IN VARIOUS STAGES OF DEVELOPMENT

BY TOPICAL AREA

A. Vegetation

1. Burke, I.C., W.A. Reiners and R.K. Olson. 1989. Topographic control of vegetation in a mountain big sagebrush steppe. IN SECOND ROUND OF REVISION. PLANNED FOR SUBMISSION TO VEGETATIO.

B. Remote sensing

1. Strong, L. L. 1986. Temporal trends in earth-atmosphere system reflectance factor for sagebrush steppe vegetation communities. 20th International Symposium on Remote Sensing of Environment. Nairobi, Kenya. Dec. 4-10. pp. 1309-1318. PUBLISHED.

ABSTRACT: Four consecutive Landsat-5 Thematic Mapper acquisitions were used to examine trends in earth-atmosphere system reflectance factors of sagebrush steppe vegetation communities following soil moisture recharge from snow melt. Significant differences in trends between vegetation communities correspond to known differences in the initiation and duration of active vegetation growth. Information on short-term vegetation processes are a valuable supplement to estimates of total vegetation cover which can be obtained using satellite brightness images at less frequent temporal intervals.

2. Strong, L.L. 1989. Mapping sagebrush steppe vegetation-soil associations using Thematic Mapper reflectance factors. PLANNED FOR REMOTE SENSING OF THE ENVIRONMENT.

3. Strong, L.L. 1989. Thematic Mapper spectral reflectance factors and albedo of sagebrush steppe vegetation-soil associations. PLANNED FOR ECOLOGY.

4. Strong, L.L. 19889. Relationships of Thematic Mapper spectral reflectance factors with vegetation cover and phytomass production of sagebrush-steppe. PLANNED FOR JOURNAL OF RANGE MANAGEMENT.

C. Nutrient cycling

1. Burke, I.C., W.A. Reiners, D.S. Sturges and P.A. Matson. 1987. Herbicide treatment effects on properties of mountain big sagebrush soils after fourteen years. Soil Science Society of America Journal. 51: 1337-1343. PUBLISHED.

ABSTRACT: Soil properties under stands of vegetation dominated by mountain big sagebrush (Artemisia tridentata ssp. vaseyana) and grass were examined 14 yr after spraying with 2,4-dichlorophenoxy acetic acide (2,4-D) to control sagebrush. Changes in only a few soil chemical properties were found after conversion to grassland. Phosphorus and K were apparently redistributed from depth to the surface 5 cm of soil by grass-dominated vegetation. Conversely, surface concentrations of N were lower under grass vegetation than under undisturbed vegetation. No changes attributable to vegetation conversion were found for total C, Na, Mg, cation exchange capacity, base saturation, pH, bulk density, or potential net N mineralization rates at any depth. In situ N-mineralization rates at a 5- to 15-cm depth were measured under and between shrubs for both vegetation conditions 15 yr after spraying. Nitrogen mineralization was similar from positions between and under former shrubs in converted (grass) vegetation, whereas in the sagebrush vegetation, mineralization rates were higher under live sagebrush plants than in interspaces between plants. Undershrub net N mineralization rates were higher under shrubs in the sagebrush vegetation than under former shrubs in the grass vegetation. Essentially, control of big sagebrush, in the absence of grazing, had no effect on site fertility. The spatial distributions of the elements and of their cycling, however, have been altered.

2. Burke, I.C., W. A. Reiners and D. Schimel. 1988. Organic matter turnover in a sagebrush steppe. Biogeochemistry. IN PRESS.

ABSTRACT: Laboratory incubations of ^{15}N-amended soils from a sagebrush steppe in southcentral Wyoming indicate that nutrient turnover and availability have complex patterns across the landscape and between microsites. Total and available N and P and microbial C and N were highest in topographic depressions characterized by tall shrub communities. Net and gross N mineralization rates and respiration were also highest in these areas, but microbial efficiencies expressing growth relative to respiration cost were highest in soils of exposed ridgetop sites (prostrate shrub communities). Similar patterns occurred between shrub and intershrub soils, with greater nutrient availability under shrubs, but lower microbial efficiencies under shrubs than between. Surface soils had higher soil nutrient pools and N mineralization rates than subsurface soils, but N and C turnover and microbial efficiencies were lower in those surface soils. All soils decreased in respiration, mineralization, and immobilization rates during the 30-day incubation period,

apparently approaching a steady-state substrate use. Soil microbial activity of the high organic matter accumulation areas was apparently more limited by labile substrate.

3. Burke, I.C. 1988. Control of N-mineralization in a sagebrush steppe. Ecology. IN PRESS.

ABSTRACT: Factors controlling N turnover in sagebrush ecosystems are separable into two groups. The first group comprises properties having strong spatial patterning at a landscape scale, but being temporally static at time scales of years or tens of years. These static properties include plant species assemblages, total soil nutrient pools, and soil texture. A second group includes properties that vary across the landscape over shorter time scales, i.e. annually, seasonally, and diurnally. These dynamic properties include soil moisture, temperature, and amount of available nutrients. This paper evaluates the landscape variability of properties in both of these groups, and examines the extent to which these factors control N turnover.

Static ecosystem properties were entered into a principal components analysis resulting in four axes of landscape variability. A statistical analysis of the relationship of net N mineralization with the principal components and with soil temperature and moisture suggested that soil microclimate and organic matter quality both control in situ turnover. Soil microclimate limited N mineralization to a short season in early spring and summer; only during this time did soil organic matter exert control. In landscape positions where soil organic matter pools were low, improved soil microclimate conditions did not increase N mineralization rates. A similar approach may be useful in evaluating control over ecosystem processes in other systems that are characterized by strong seasonal and spatial variability.

4. Matson, P.A. and K. Coppinger. 1989. Nitrous oxide flux from sagebrush steppe ecosystems. MANUSCRIPT PLANNED FOR BIOGEOCHEMISTRY.

5. Coppinger, K., W.A. Reiners, I.C. Burke and R.K. Olson. 1989. Net erosion on a sagebrush steppe landscape as determined by ^{137}Cs distribution. IN SECOND ROUND OF REVISION FOR SUBMISSION TO SOIL SCIENCE SOCIETY OF AMERICA JOURNAL.

ABSTRACT: Redistribution of soils within and between ecosystems can have important effects on ecological properties including soil and vegetation characteristics, primary production and nutrient cycling. This study examined patterns and assessed transport mechanisms of soil erosion and deposition in a native sagebrush steppe landscape in south central Wyoming using ^{137}Cs. In this little-disturbed site, regression analysis failed to produce consistent relationships between ^{137}Cs and selected landscape variables. ^{137}Cs values were generally the same across the site, suggesting that intermediate-scale (aproximately 100 m)

fluvial soil transport is unimportant in this system over time since bomb-test deposition occurred. Analysis of variance showed that in windswept landscape positions, ^{137}Cs was significantly higher under shrubs than between them. These results suggest that wind-driven redistribution has occurred at a small scale (0.5 - 10 m). Even though ^{137}Cs data indicate that intermediated scale transport is not occurring, analysis of the soil fine fraction shows net transport of fines donwslope. These results suggest that in this sagebrush ecosystem, soil redistribution by fluvial erosion occurs too slowly to be determined by bomb test ^{137}Cs.

D. Modeling

1. Ojima D.S., I.C. Burke and W.J. Parton. 1989. Adaptation of the CENTURY ecosystem simulation model to sagebrush steppe. FIRST DRAFT SCHEDULED FOR END OF DECEMBER, 1988; SUBMISSION PLANNED FOR ECOLOGICAL MODELING.

2. Reiners, W.A., L.L. Strong, P.A. Matson, I.C. Burke and D.S. Ojima. 1988. Estimating biogeochemical fluxes across sagebrush-steppe landscapes with Thematic Mapper imagery. SUBMITTED TO REMOTE SENSING OF THE ENVIRONMENT.

ABSTRACT: Thematic Mapper (TM) satellite data were coupled to an ecosystem simulation model to simulate variation in nitrogen mineralization over time and space in a sagebrush steppe. This system of data inputs and calculations provides estimates of ecosystem properties including rates of biogeochemical processes over extensive and complex landscapes, and under changing management and climatic conditions. Efforts to measure late-spring snow cover and distribution, the major source of soil moisture in this semi-arid system, failed because of insufficient frequency of satellite overpasses at this cloudy time of year.

3. Matson, P.A., W. A. Reiners, L.L. Strong, I.C. Burke and D.S. Ojima. 1989. Spatial-temporal modeling of sagebrush ecosystems using TM-CENTURY spatial model. INITIATION OF THIS MANUSCRIPT PENDING COMPLETION OF NO. 1 ABOVE.

PAPERS PRESENTED AT SCIENTIFIC MEETINGS

BY YEAR

1986

Burke, I.C. and W. A. Reiners. 1986. Patterns of nitrogen flux rates across a sagebrush landscape. Presented at Contributed Paper Session 86, 71st Annual Meeting of the Ecological Society of America, IV International Congress of Ecology, Syracuse, N.Y., 10-16 August 1986. Abstract: Congress Program: p. 106.

Matson, P.A. 1986. Biogeochemical Processes in sagebrush ecosystems: interaction of terrain and management practices. Presented at the Landsat TM/AO Workshop, NASA/Goddard Space Flight Center, Greenbelt, Maryland, 3-5 September 1986. Abstract: Proceedings of Landsat Workshop p. 279-293.

Reiners, W.A., P.A. Matson, L.L. Strong and I.C. Burke. 1986. Estimating biogeochemical properties of a sagebrush steppe with remote sensing. Presented at INTECOL Symposium: Modeling and remote sensing of Biogeochemical Processes, IV International Congress of Ecology, Syracuse, N.Y., 10-16 August 1986. Abstract: Congress Program: p. 284.

Strong, L.L. 1986. Temporal trends in earth-atmosphere system reflectance factor for sagebrush steppe vegetation communities. Presented at the Twentieth International Symposium on Remote Sensing of Environment, Nairobi, Kenya, 4-10 December 1986. Published in proceedings (see above).

1987

Burke, I.C. and W.A. Reiners. 1987. Predicting nitrogen mineralization rates across a sagebrush steppe from topographic variables. Presented at 72nd Annual Meeting, Ecological Society of America, Columbus, Ohio, 9-14 August. Abstract: Bulletin of the Ecological Society of America 68(3):273.

Matson, P.A., L.L. Strong, W.A. Reiners and I.C. Burke. 1987. Predictions of biogeochemical processes in sagebrush ecosystems through the use of remote sensing. Presented at International Geoscience and Remote Sensing Symposium. Ann Arbor, Michigan, 18-21 May 1987. Abstract:1:449-450.

Matson, P.A. and L.L. Strong. 1987. Biogeochemical processes in sagebrush ecosystems. Presented at Landsat TM/AO Workshop, Santa Barbara, California, September, 1987. Abstract: Proceedings of Landsat TM/AO Workshop.

Strong, L.L. 1987. Inventory and monitoring of sagebrush steppe using temporal Thematic Mapper satellite data. Presented at the 40th Annual Meeting of the Society for Range Management, Boise, Idaho, 8-13 February 1987.

1988

Coppinger, K., C. Volksmann and P. Matson. 1988. Relationships between nitrous oxide flux and soil nitrogen in sagebrush steppe. Presented at 73rd Annual Meeting, Ecological Society of America, Davis, California, 14-19 August, 1988. Abstract: Bulletin of the Ecological Society of America 69(2):106.

Reiners, W.A., L.L. Strong, P.A. Matson, I.C. Burke and D.S.

Ojima. 1988. Estimating biogeochemical fluxes across sagebrush-steppe landscapes with Thematic Mapper imagery. Presented at Final Landsat TM/AO Workshop, Greenbelt, Maryland, 22-25 August 1988. To be published under same title in dedicated volume of Remote Sensing of the Environment.